Mucool Test Area
Cryo-system Design

Fermilab/ Beams Division/ Cryogenic department
Ch. Darve, B. Norris, A. Martinez, L. Pei

Main requirements for the cryo-system:

- ✓ Density fluctuation in the LH2 should be smaller than +/- 2.5 %
- ✓ P=1.2 atm=17.6 psia=0.12 MPa
- ✓ Subcool temperature => 17 K

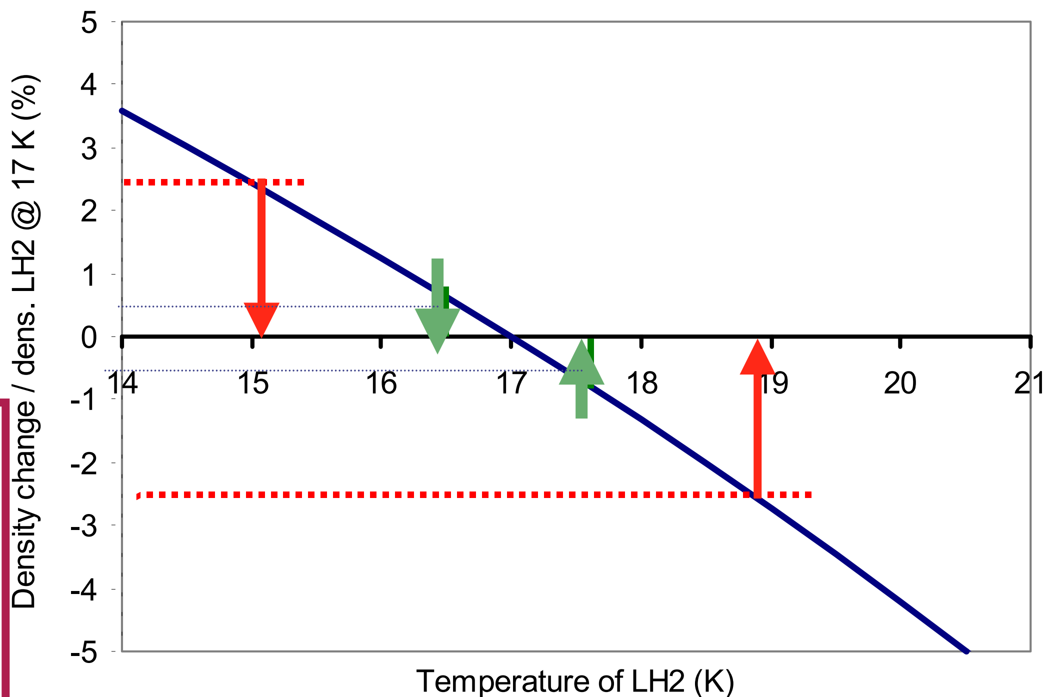
1- Stay bellow boiling point

2- Temperature difference < 1 K

(using a large safety factor)

- in absorber volume

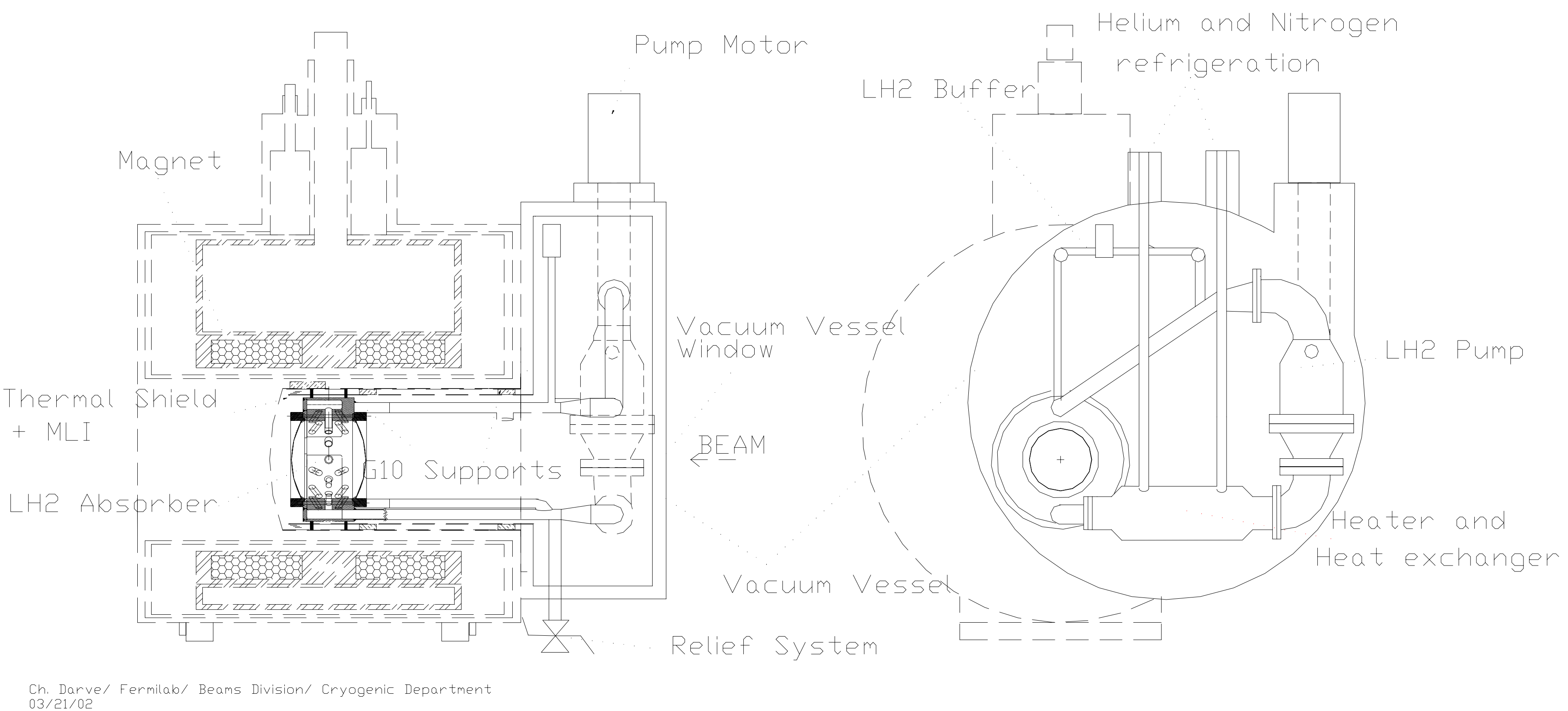
- in the cryo-system



FERMILAB
B D/ Cryogenic

Part IV – A look at the Windows and Absorber Vessel

Overview of MuCool Test Area cryo-system - cryostat



Part IV – A look at the Windows and Absorber Vessel

Overview on the Absorber Pump flow method

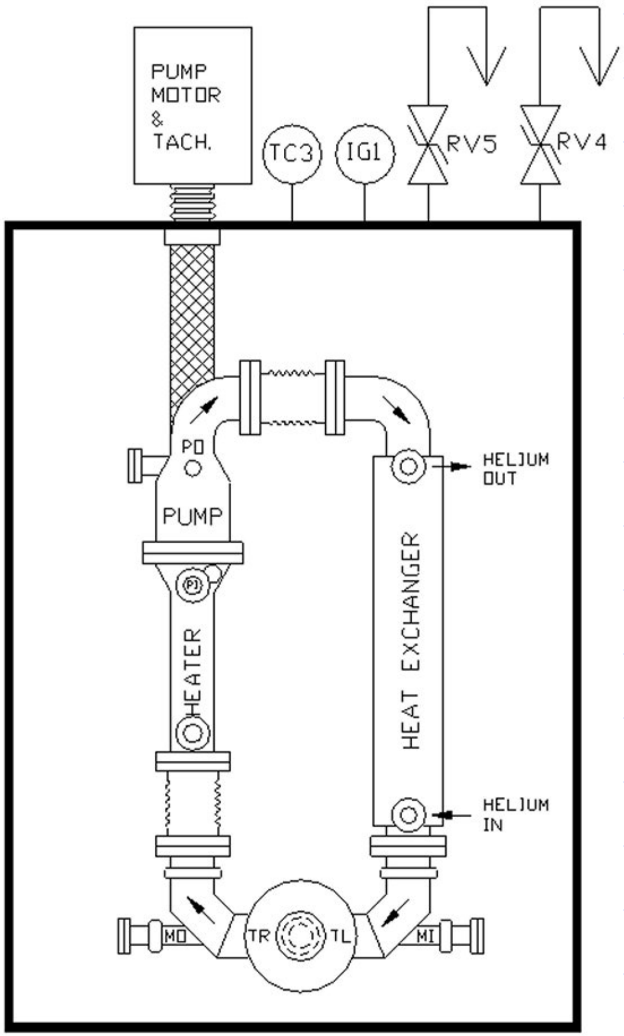
FERMILAB
BD/Cryogenic Department

The **LH_2 pump** was designed and built by Caltech as a spare pump for the SAMPLE experiment (½ dia. of the pump used in E158)

Purpose:

To circulate LH_2 in a close loop and provide force flow to remove the energy loss from the LH2 absorber, with $\Delta T<1$ K

Schematic of SAMPLE



Max. available flow at 17 K, 1.2 atm = 450 g/s

Reference:

"E.J. Beise et al., A high power liquid hydrogen target for parity violation experiments, Research instruments & methods in physics research (1996), 383-391"

FERMILAB
BD/Cryogenic Department

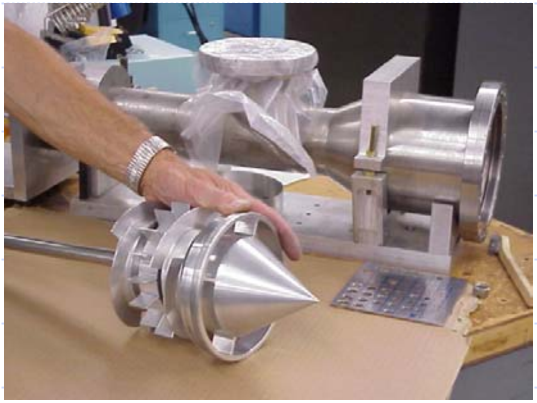
Part IV – A look at the Windows and Absorber Vessel

Overview on the Absorber Pump flow method

The LH_2 pump is composed of:

⇒ two impeller blades => to straighten the flow
⇒ three stators => to accelerate the flow
⇒ two cones => to reduce the impedance of the flow

Materials:
Impellers: Aluminum 6061 T6
Housing: 304



A motor located at room temperature drive the pump:
⇒ typical Tevatron Wet Engine 2 HP motor will be used

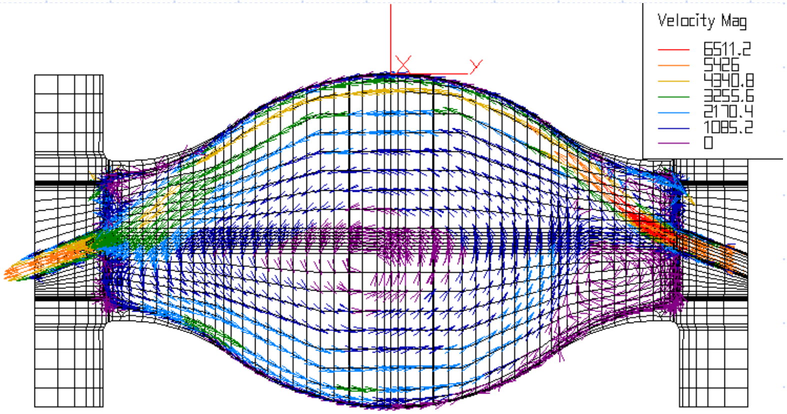
Part IV – A look at the Windows and Absorber Vessel

Overview on the Absorber Pump flow method

FERMILAB
BD/Cryogenic Department

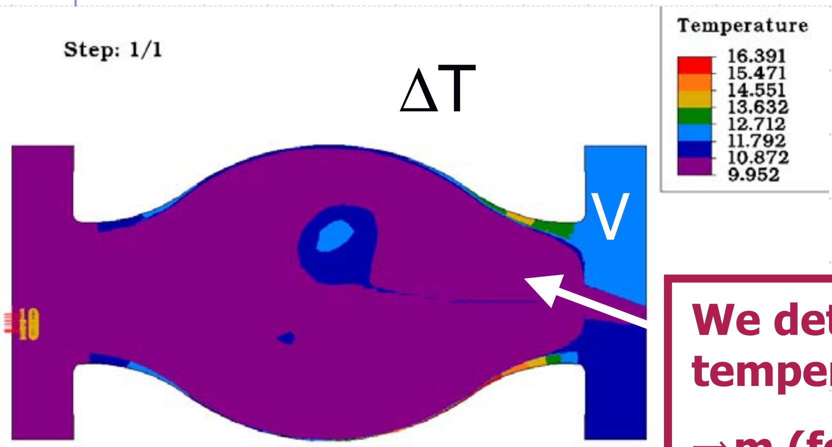
What is the mass flow needed to cool the beam?

Simulation of the flow by Wing Lau/ Charles H. Holding (Oxford) using Algor 2 D model



How to use the results?

Determine velocity so that ΔT<1K



We determine the velocity, V, for the addoc temperature difference, ΔT:

⇒m (for given ΔT, nozzle geometry and LH2 prop.)

⇒ΔP(for LH_2 cryoloop)

SEE WING LAU TALK

Part IV – A look at the Windows and Absorber Vessel

Overview on the Absorber Pump flow method

We do need to understand the thermo-hydraulic behavior of the LH2 absorber

- **Example: Case of the maximum available flow by the LH2 pump**

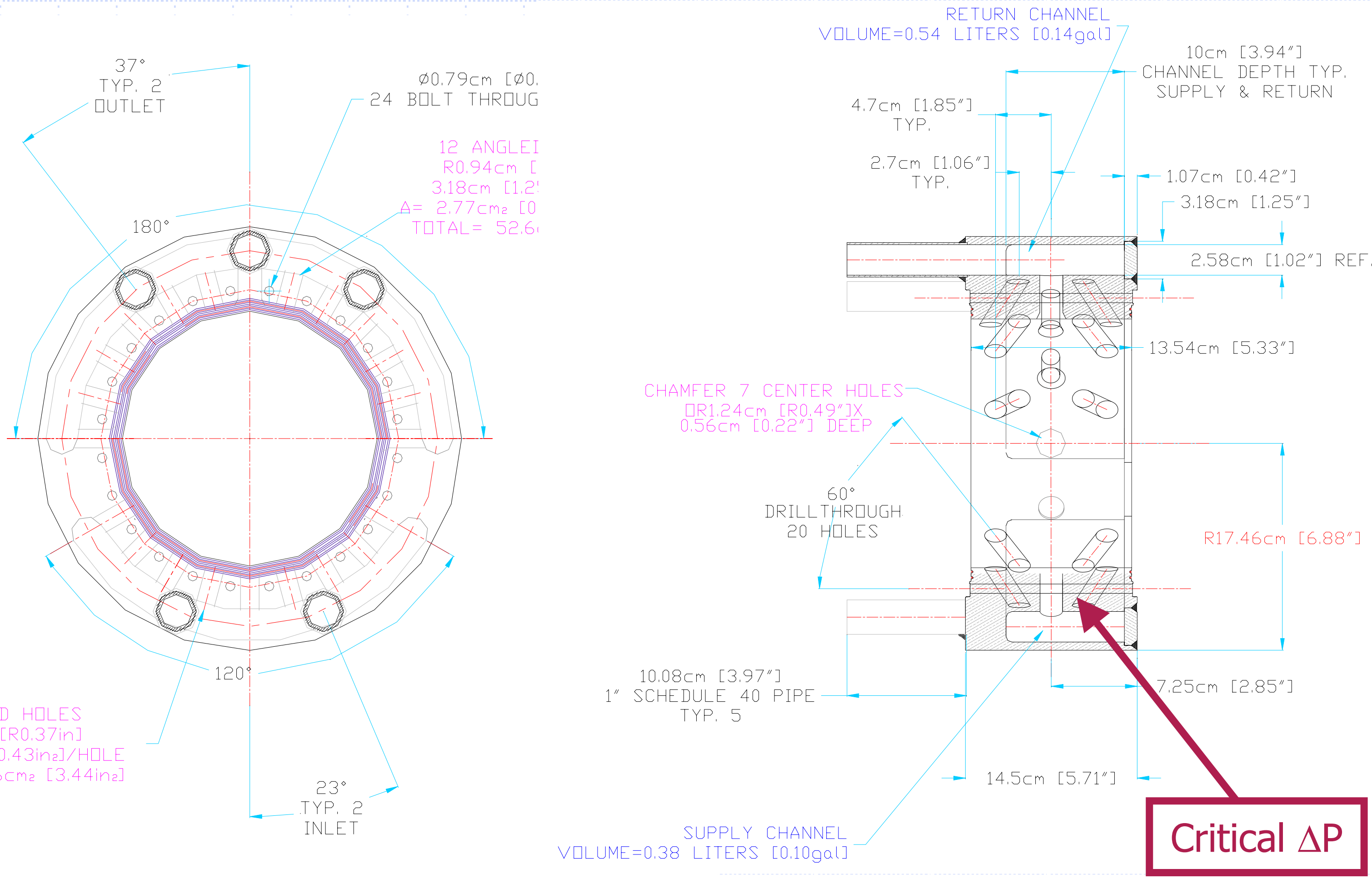
In order to be functional the LH2 absorber would need to be optimized (goal: reduction of the pressure drop)

Proposed changed: If V=4 m/s then m=450 g/s

Current geometry	Requested geometry
LH2 abs:	**LH2 abs:**
Nozzle dia.= 0.6″	Nozzle dia.= 0.43″
8 Supply nozzles	11 Supply nozzles
12 returns nozzles	15 returns nozzles
Piping in the magnet bore:	**Piping in the magnet bore:**
40 cm long IPS 1″ pipes	20 cm long IPS 1″ pipes
10 cm long IPS 2″pipe	30 cm long IPS 2″pipe

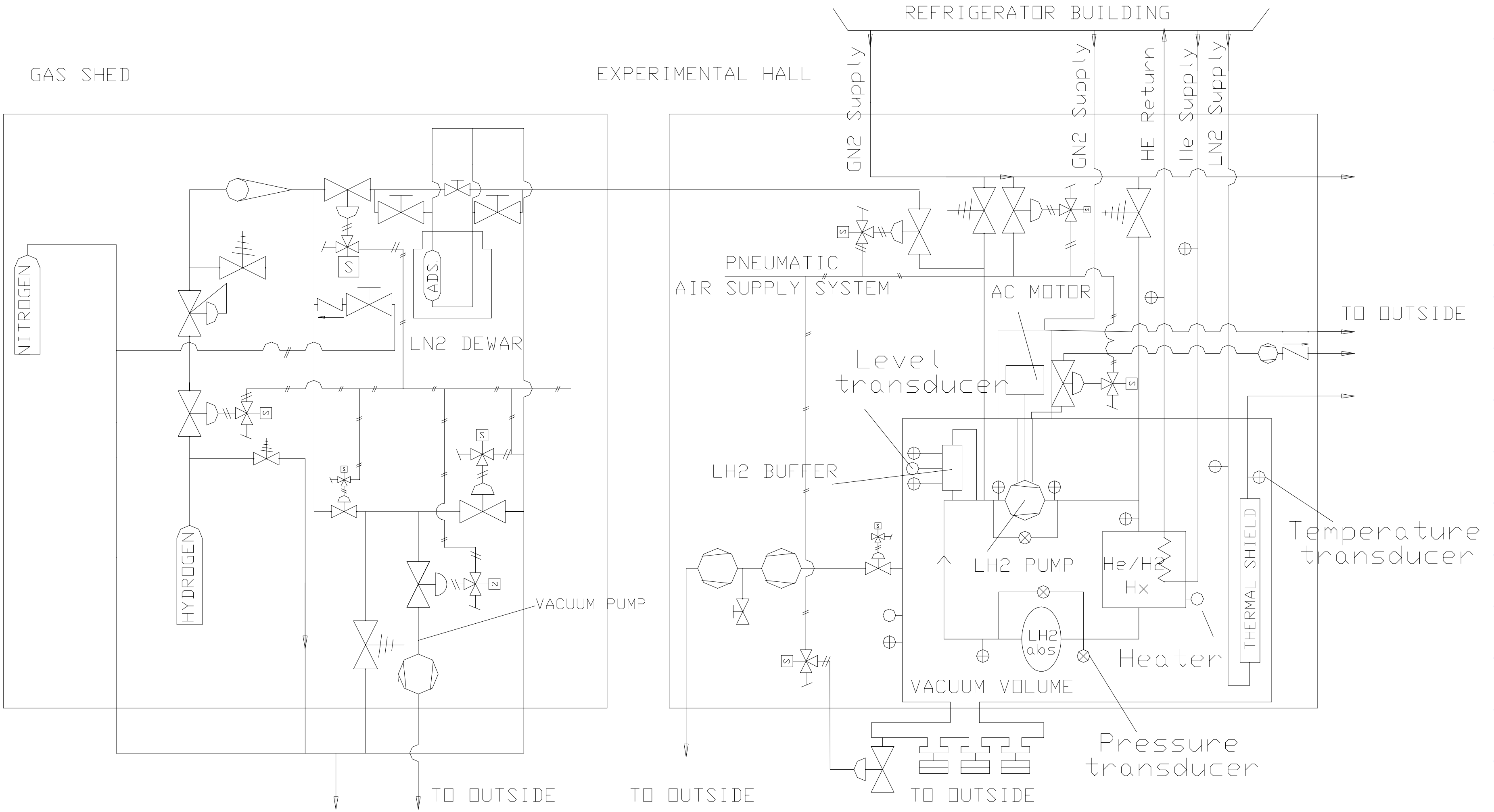
Part IV – A look at the Windows and Absorber Vessel

LH2 Manifold absorber (by E. Black)



Part V – A look at the Hydrogen Proposal

Process and Instrumentation Diagram



FERMILAB

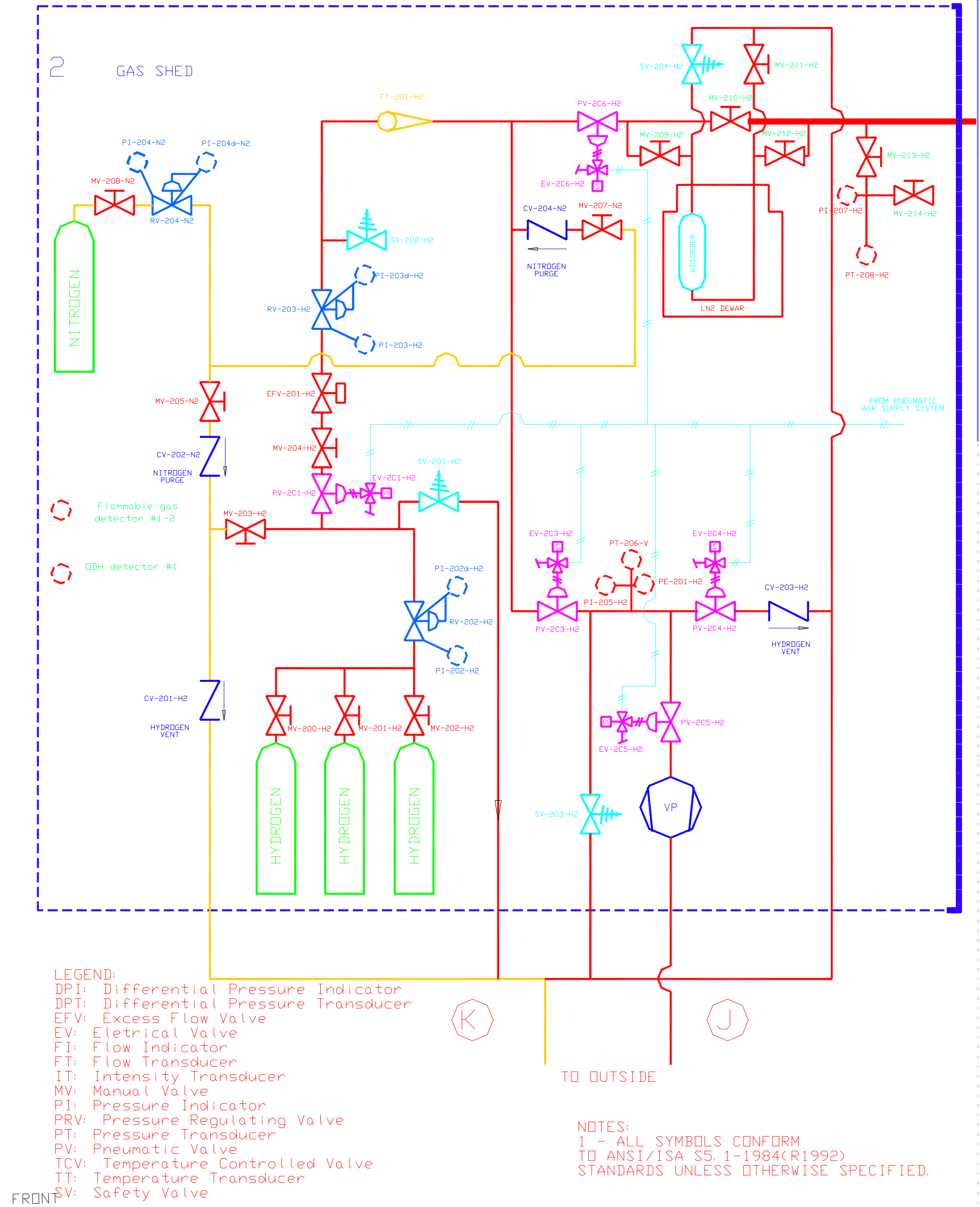
BD/Cryogenic Department

Equipment:

- Gas H2 bottle
- Gas N2 bottle
- O2 adsorber
- Vacuum pump
- Flam. Gas detector
- ODH detector
- Pneumatic air supply sys.

Instrumentation:

- Flowmeter Transducer
- Pressure Reg. Valve
- Safety Valve
- Manual Valve
- Excess flow Valve
- Pneumatic Valve
- Electrical Valve
- Check Valve
- Pressure Indicator
- Pressure Transducer



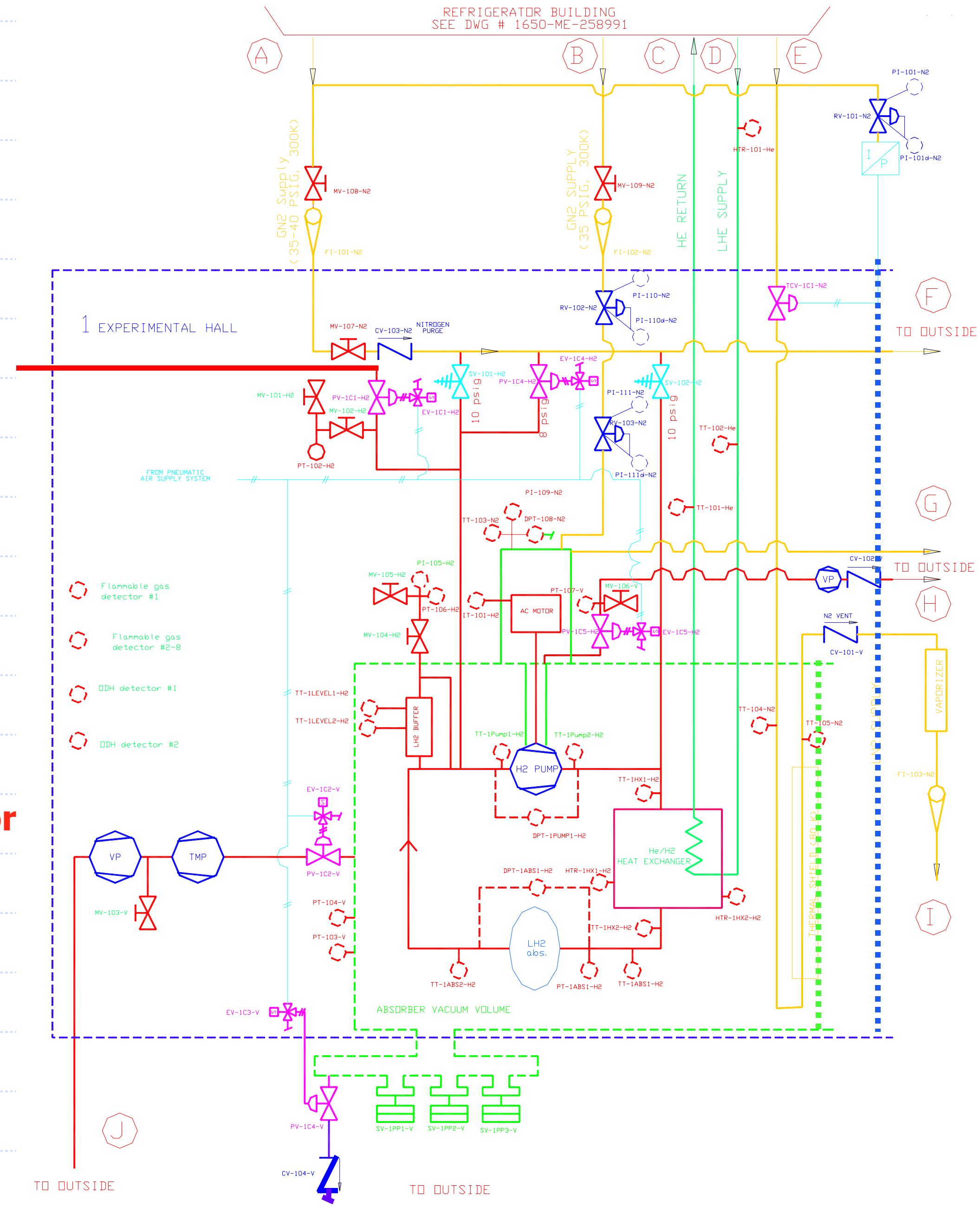
FERMILAB
BD/Cryogenic Department

Equipment:

- Roughing Vacuum pump
- Turbo Molecular pump
- Gas He Supply/Return
- Gas N2 Supply/Return
- Liq. N2 Supply/Return
- Vaporizer
- Flam. Gas detector
- ODH detector
- Pneumatic air supply sys.

Instrumentation:

- Temperature Transducer
- Pres. Transducer and Indicator
- Flowmeter Indicator
- Heater
- Safety Valve
- Temperature Controlled Valve
- Pressure Reg. Valve
- Manual Valve
- Electro+ Pneumatic Valve
- Check Valve



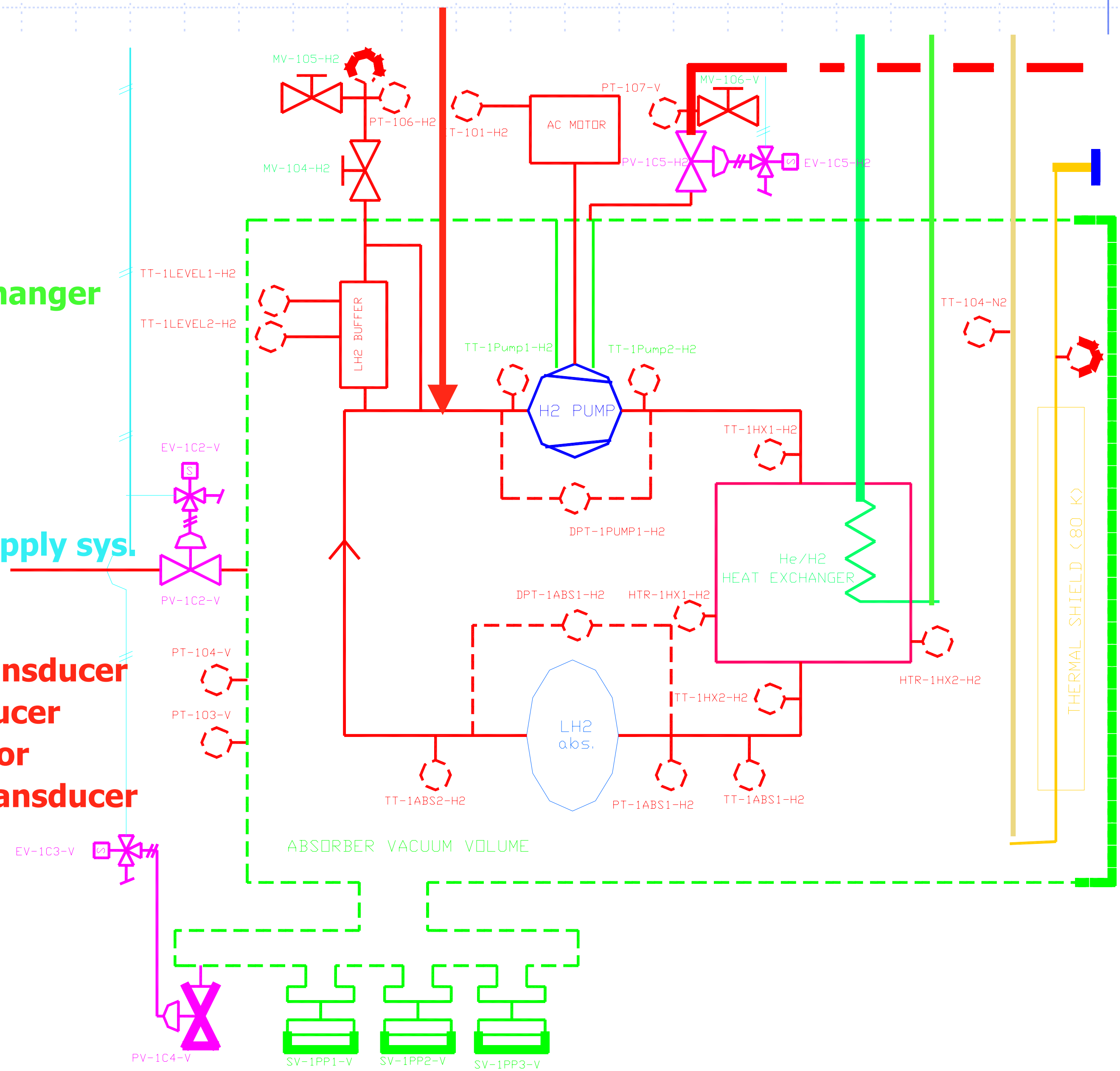
FERMIL
BD/Cryogenic

Equipment:

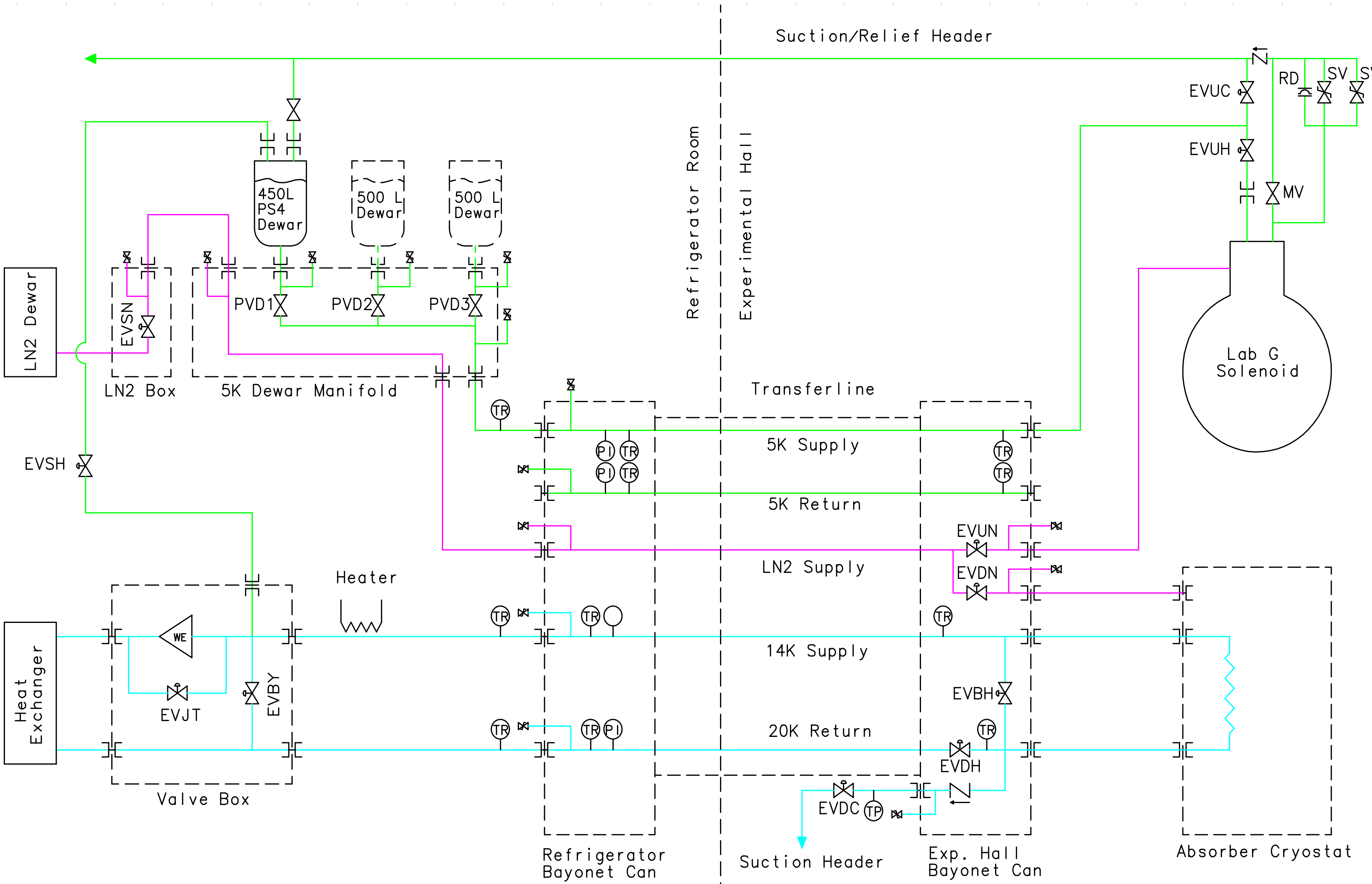
- Absorber
- He/H2 Heat Exchanger
- LH2 pump
- AC motor
- LH2 buffer
- Vacuum pump
- Thermal shield
- Pneumatic air supply sys.

Instrumentation:

- Temperature Transducer
- Pressure Transducer
- Pressure Indicator
- Diff. Pressure Transducer
- Heater
- Safety Valve
- Manual Valve
- Pneumatic Valve
- Electrical Valve
- Check Valve



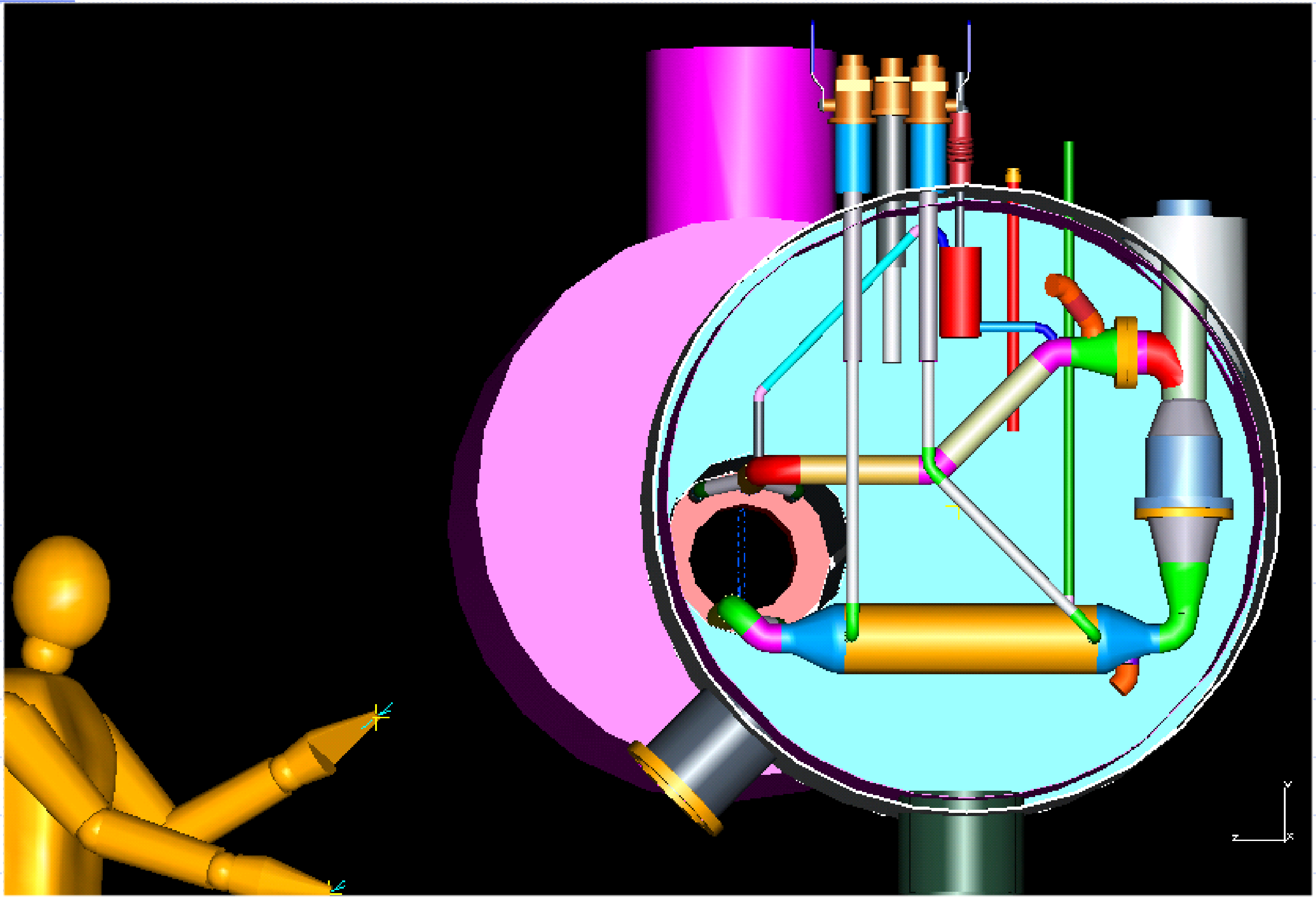
MuCool Helium Flow/Equipment Schematic



FERMILAB
BD/Cryogenic Department

Part V – A look at the Hydrogen Proposal

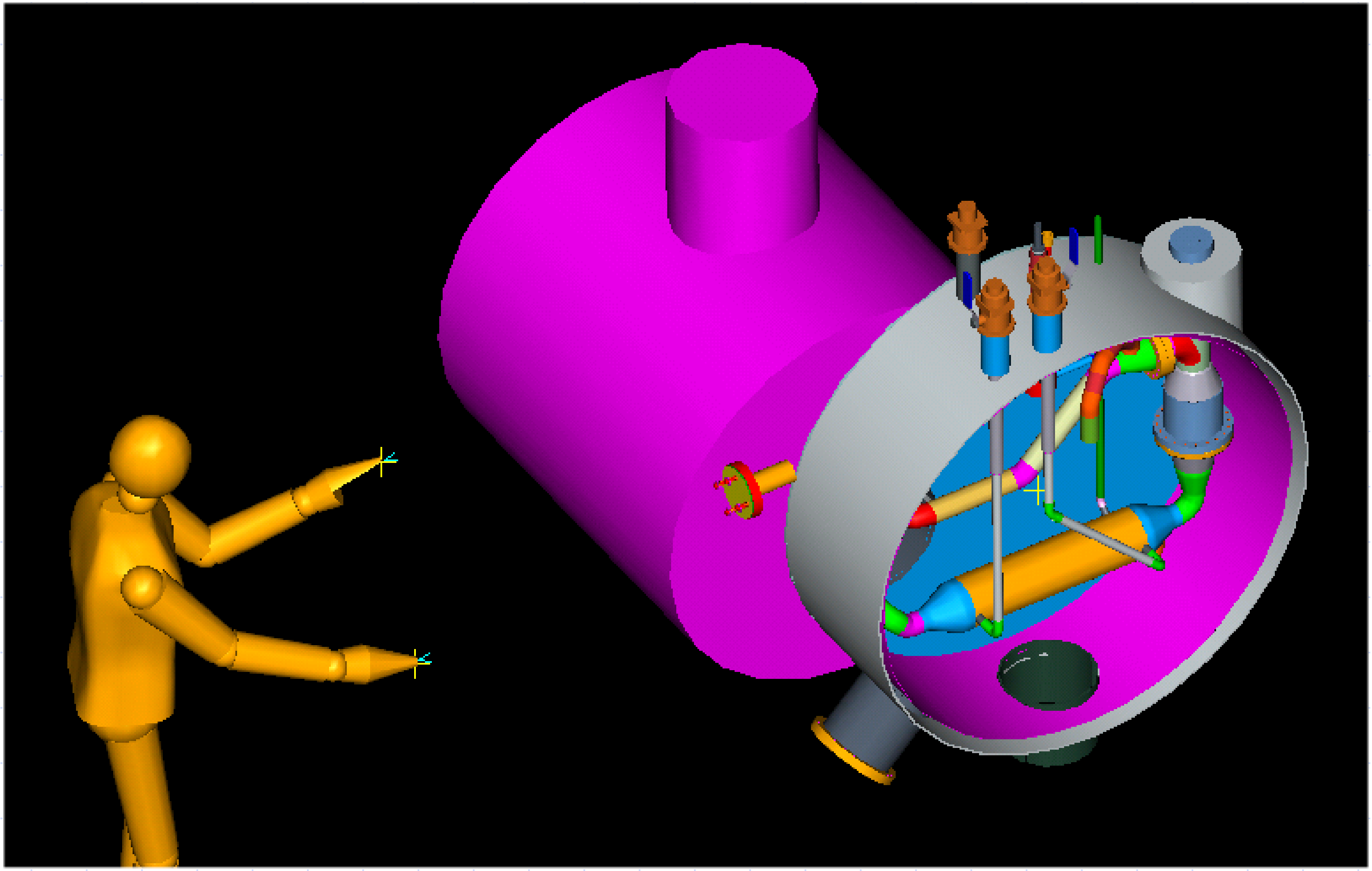
Cryo-system design



FERMILAB
BD/Cryogenic Department

Part V – A look at the Hydrogen Proposal

Cryo-system design

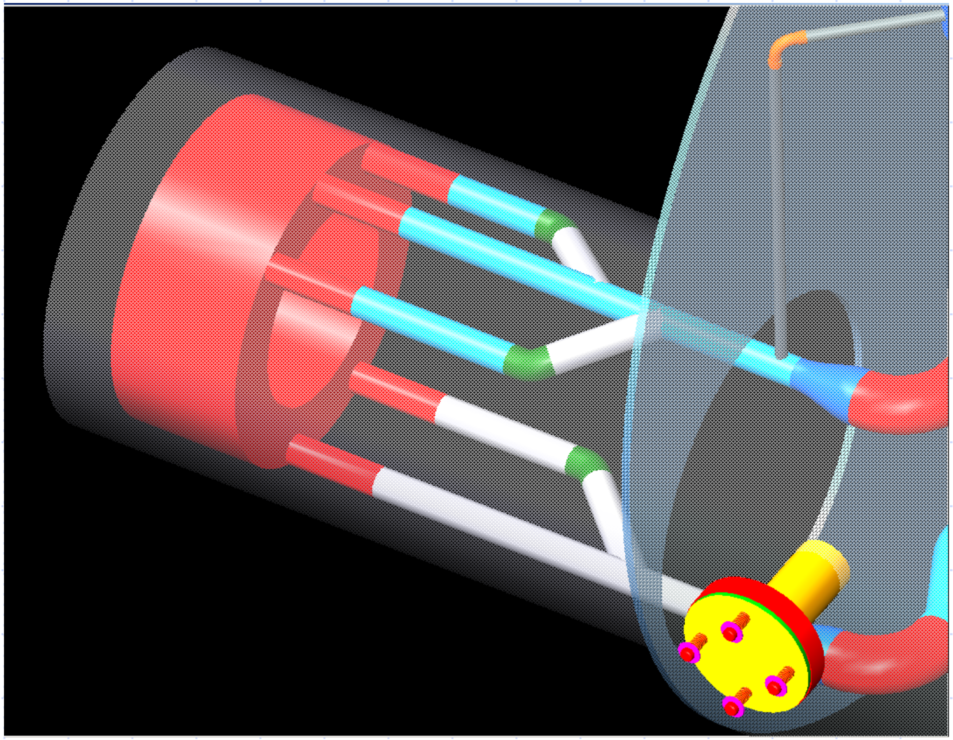


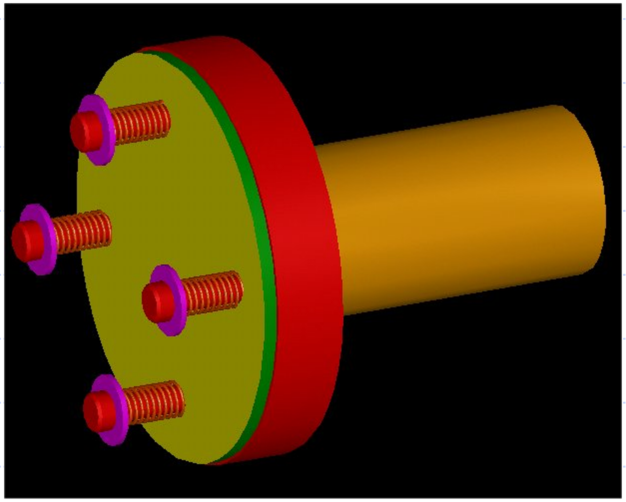
Part V – A look at the Hydrogen Proposal

Cryo-system design

1 - Cryostat Set-up assembly:

- **Piping IPS1, IPS2 Sc5, Bimetallic transitions…**
- **Safety devices: Parallel plate, AGCO**



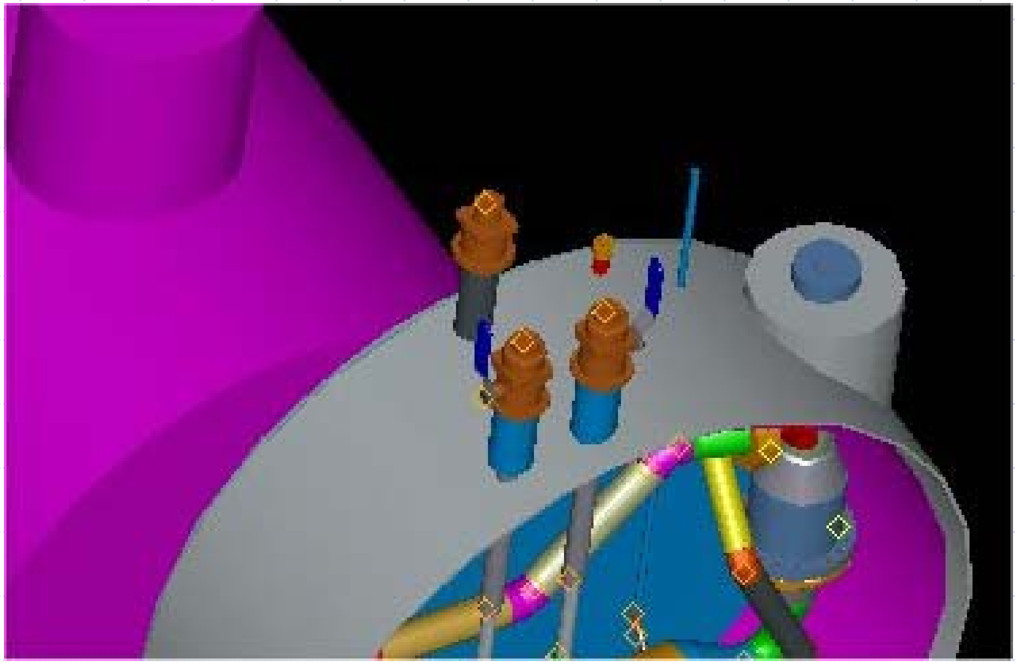


Part V – A look at the Hydrogen Proposal

Cryo-system design

1 - Cryostat Set-up assembly:

- Thermal + MLI,
- Vacuum vessel,
- Connection to pumping sys,
- Transfer lines and bayonets.

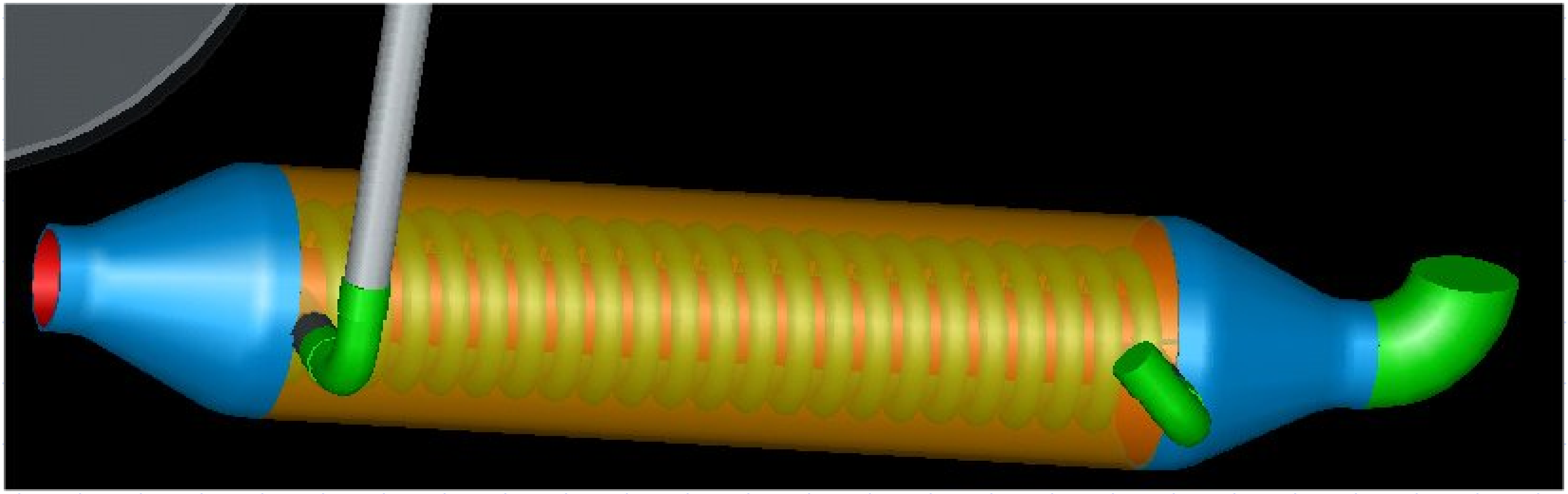


Part V – A look at the Hydrogen Proposal

Cryo-system design

2- Heat exchanger assembly:

- **Copper coil,**
- **Outer shell,**
- **Diameter reduction,**
- **He inlet and outlet,**



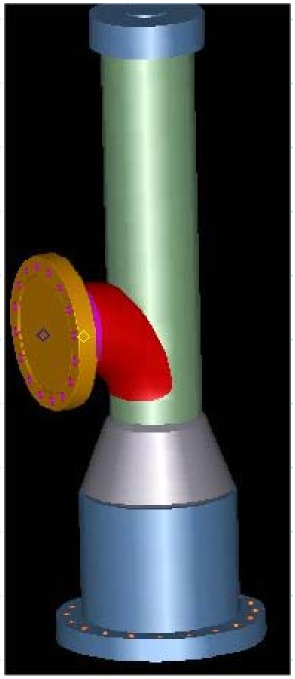
FERMILAB
BD/Cryogenic Department

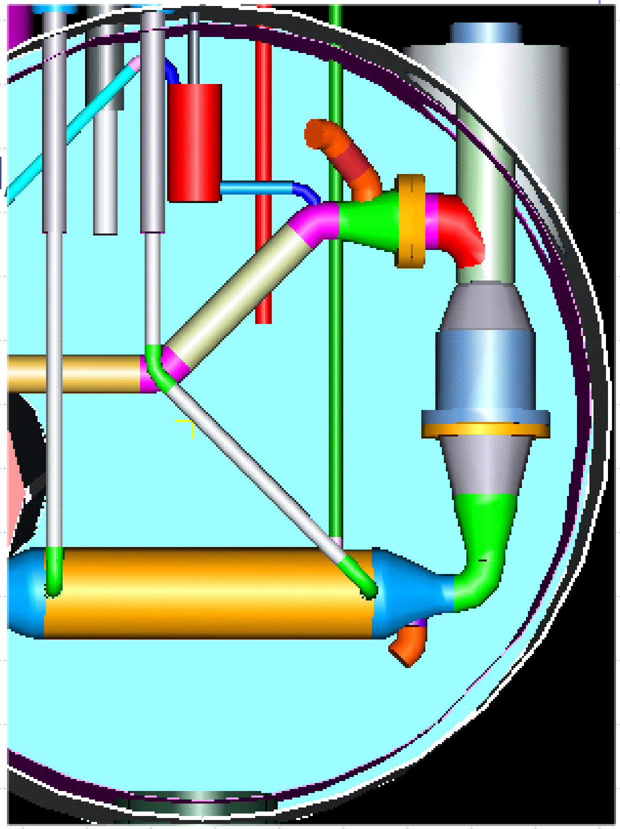
Part V – A look at the Hydrogen Proposal

Cryo-system design

3- LH2 Pump assembly:

- **Pump torque transition,**
- **Motor outer shield,**
- **Cooling system,**
- **Pumping system of the outer shield,**
- **Relief valves piping.**





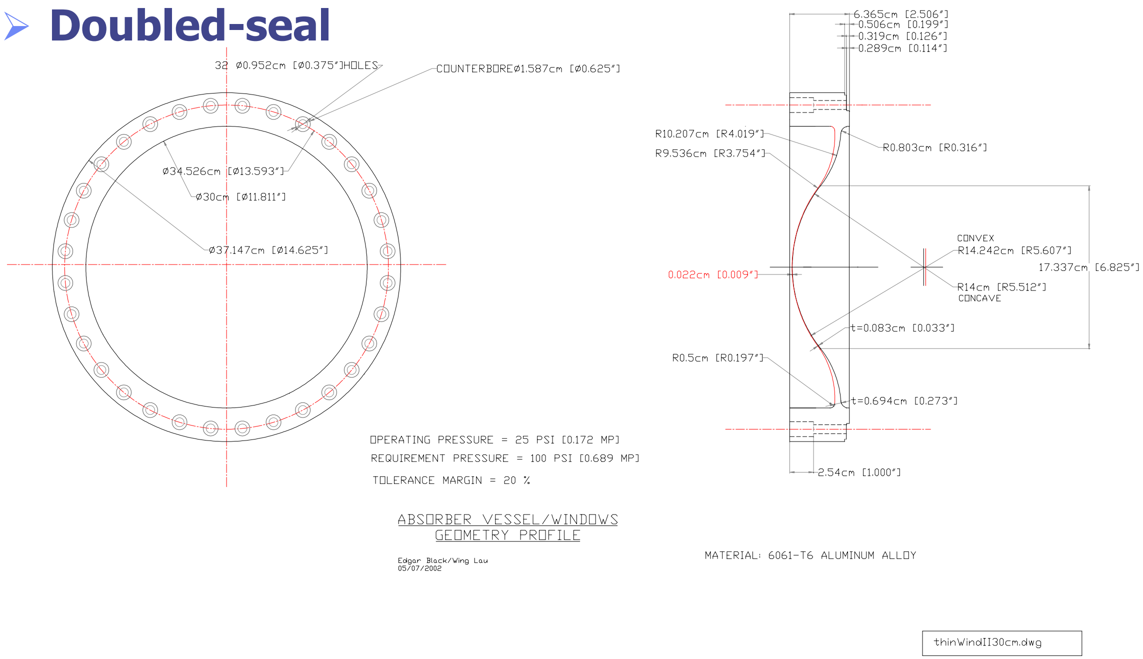
FERMILAB
BD/Cryogenic Department

Part V – A look at the Hydrogen Proposal

Cryo-system design

4- Absorber assembly:

- **Implement Ed Black/Wing Lau drawings with cryostat vacuum vessel windows, absorber**
- **Design interface of the systems (flanges, piping)**
  - **Absorber manifolds**
  - **Windows in the loop**
  - **Doubled-seal**



Part IV – A look at the Windows and Absorber Vessel

Overview on the Absorber Pump flow method

Status:

- **In order to design the total cryo-system, we do need to simulate the optimal flow regime (Oxford/cryo dpt).**
- **Focus:**
  - **Thermo-hydraulic behavior of LH2 absorber for which ΔTmax=1 K (and 3 K): ΔT, ΔP , mass flow, power distribution**
  - **Influence of the beam distribution (volume-surface distribution)**
- **Upgrades from the Algor model:**
  - **Geometry upgrade, temperature upgrade**
  - **Influence of the nozzle number to reduce the hot spot=>3D model**

References:

http://www-bdnew.fnal.gov/cryo-darve/mu_cool/mu_cool_HP.htm
ICEC19 article - Cryogenic design for a liquid hydrogen absorber system